Idaho National Engineering and Environmental Laboratory

LASER-ASSISTED ELECTROCHEMICAL PROCESS FOR HIGH PRECISION COATING AND PATTERNING APPLICATIONS

Description

The design, development and application of an automated, high precision coating and three-dimensional patterning system is proposed. The system is based on a laser-assisted electrochemical processing technology under investigation at the Idaho National Engineer-ing and Environmental Laboratory (INEEL). These studies have shown that laser treatment during an electrochemical process can significantly increase metal deposition rates and efficiencies over traditional bath processes. Metals deposited via the technique display fewer voids, better adhesion, and superior hardness properties. The process has the potential for controlling deposition and removal of materials with laser beam precision and is compatible with a variety of metals, alloys and composites. In addition, the system can be designed as an automated, closed-loop, process which can operate with very dilute solutions; thereby, conserving precious metals, minimizing wastes and reducing personnel exposure to hazardous chemicals.

Background

A wide range of technologies are based on electrochemical phenomena. For more than a century, electrochemical processes have provided essential materials, many of which cannot be economically produced by any other means. Current markets include materials and chemicals production, microelectronics, sensors, surface processing, membrane separations, advanced batteries, fuel cells and corrosion control.

In recent years, researchers at the INEEL have demonstrated the potential benefits of a rapid, laser-assisted electrochemical process. In the process, a laser is directed to the cathode, or workpiece, of an electrochemical cell while the cathode is supplied with a high speed stream of plating solution. The laser irradiation induces a highly localized temper-ature gradient at the metal/solution interface, resulting in the migration of ions in the solution to either the hot or cold region, producing a concentration gradient. This pheno-menon is called the Soret effect and is believed to be the major contributing factor in the plating enhancement observed in the INEEL studies. (Patent Pending, D. F. Glenn and J. K. Partin, EGG-PI-673, “Method for Increasing Plating Rates and Current Efficiencies of Electroplating Processes - Soret Assisted Electrodeposition “)

Using a Nd:YAG laser, plating rates of 120 mils per hour and current efficiencies of 60%, have been observed for chromium with an unoptimized system using a dilute solution (2 M) of chromic acid. Bath electrodeposition of chromium has a current efficiency of approxi-mately 15% with an average plating rate of 1 mil per hour. The process is capable of depositing and removing a variety of metals and alloys. Metals deposited via the technique display fewer voids, better adhesion, and superior hardness properties. If the voltage is held at a level just below where plating (or etching) normally occurs, the laser can be used to drive the process, thus offering the potential for an extremely high precision.

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Applications

The integration of a laser into an electrodeposition process offers unique possibilities in the manufacture of coatings and parts including:

- Maskless High-Speed Patterning of Electrodeposited Metal
- Near-Net Shape Electroforming
- Laser-Initiated Electroless Plating
- Electrochemical Joining
- Electrochemical Etching
- Co-Deposition of Unique Metal Combinations
- Deposition of Difficult-To-Plate Metals
- Self-Lubricating and Improved Wear Coatings
- Microfabrication
- More Efficient Use of Plating Solutions and Reduction of Plating Wastes

The potential for manufacturing components of micron dimensions is of particular interest. To date, most micromechanical elements of 100 microns or less, in size have been fabricated by micromachining techniques developed for semiconductor devices. Materials have been limited to silicon, silicon dioxide, silicon nitride, polymide and some metals. Some geometries, loops and coils for example, are also difficult to achieve using these techniques. The long term goals of these efforts are to incorporate micromechanical components, including sensors, actuators, logic circuits, and electronics into integrated sensing systems on chips. The tools available through the further development of the laser-assisted electrochemical technology could greatly enhance this effort. In particular, the process offers advantages in its ability to work with a variety of metals and alloys.

Specific applications might include the production of novel coatings and components for the aerospace and automotive industries, integrated circuit boards, electrical connectors, mechanical components, tool dies, RF shielding, “smart skin” fabrication, and biomedical components.

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